Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Interface Requirements Document (IRD)

Space Segment (SS)
To
GOES Rebroadcast (GRB) Service

Draft

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To verify the correct version of this document, please contact the GOES R Series Requirements Management Office on 301-286-7898

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1 Introduction

The Geostationary Operational Satellite System Series R (GOES-R) is an operational mission planned to make observations from geostationary orbit. The GOES-R mission will provide an Advanced Baseline Imager (ABI), Hyperspectral Environmental Suite (HES), Space Environmental Monitor (SEM) suite, Solar X-ray Imager (SXI), Lightning Mapper (LM) and auxiliary communications services for data collection, search and rescue and data relay. The GOES-R System will provide an expanded capability series of spacecraft to follow those developed and launched under the GOES N-Q Program. Six GOES-R Mission Segments interface and function to support the total GOES-R mission. They are (bold titles are items covered in this IRD):

- **Space Segment (SS)**
- Launch Support Segment (LSS)
- Ground Located - Command, Control, and Communications Segment (GL-C3S)
- Product Generation and Distribution Segment (PGDS)
- User Interface Segment (UIS)
- Archive and Access Segment (AAS)

As part of the Space Segment (SS), the GOES-R will support several NOAA auxiliary services:

- **GOES Rebroadcast (GRB) Service**
- Low Rate Information Transmission (LRIT) Service
- Emergency Managers Weather Information Network (EMWIN) Service
- Data Collection System (DCS)
- Search and Rescue (SAR) Service

1.1 Purpose

The purpose of this document is to describe and specify the functional and performance interface requirements for the communication links between the GOES-R Space Segment (SS) and Direct Readout Ground Stations (DRGS) of the GRB data user community. This document it also intended to provide a basis for the subsequent development of a SS-GRB Interface Control Document (ICD).

1.2 Scope

The interface supports the flow of data from the SS and to the GRB ground segments. The GRB transponder in the GOES-R Series spacecraft performs a conversion of the uplink X-band signal to the downlink L-band. Only those parameters, which are necessary to specify the interface requirements, will be referenced here; additional transponder performance requirements will be contained in a satellite performance specification. Consequently, this IRD:

Identifies required RF links between the SS and the GRB ground segments,
Establishes functional and performance requirements related to these links.

1.3 Document Overview

This document contains six sections and three appendices.

Section 1 explains the purpose and scope of the IRD. It contains a list of applicable and reference documents relevant to the interface.
Section 2 describes the GRB system functional elements that must be supported by the subject interfaces.
Section 3 describes the characteristics of the Direct Readout Ground Stations (DRGS) relevant to the interface with the GOES-R Space Segment.
Section 4 provides the functional and performance requirements that must be met by the SS to support the data link interfaces.
Section 5 specifies the overall data link performance that must be met under specified assumptions.
Section 6 provides a reference listing of the document location for the characteristics of the SS and GRB specifications.
Section 7 lists issues and TBDs/TBRs in the IRD.
Section 8 provides a requirements traceability matrix.
Section 9 lists abbreviations and acronyms used in the IRD.

1.4 Reference Documents

The following documents [1] through [3] contain information about the GRB Service.
[1] Performance Specification for the GOES-N,O,P,Q, S-415-22, Attachment B, Table 10, 27 August 1997, NASA/GSFC]
[2] GOES N-Q Space-to-Ground Interface Control Document, Doc. No. DS80667-H00-003, Version 1.0, 31 March 1999
The following document contains information about the capabilities of the NOAA Command and Data Acquisition Stations (CDAS):
[3] NOAA/NESDIS Antennas and RF System Capabilities Handbook, NOAA/OSD3-2001-0043R0UD0, 10 August 2001

2 GOES Rebroadcast (GRB) Service and Interface Description

2.1 General Description

The GRB data service provides the stream of the GOES processed instrument data, other NWS products and related information to the weather research and Earth sciences community.
The GRB link relays the GOES instrument data generated at the CDAS, independently through the GOES-East and GOES-West satellites, and downlinks to the Spacecraft Operation Control Center (SOCC) in Suitland, MD and other varied GRB users.
This system provides link connectivity between outlying Direct Readout Ground Stations (DRGS) including NOAA's NWS, other research organizations and the NOAA Command and Data Acquisition Stations (CDAS) at Wallops, VA. GOES-R satellites located over the Pacific and Atlantic oceans provide support to the DRGS and to all the weather research and Earth sciences community.
Satellite GRB transponder is bent-pipe, i.e., receiving the uplinks within a certain frequency band, translating to a new frequency band, amplifying, and retransmitting on the downlink. The information data rate is described in Table 2.1.2-1. Each satellite

employs an antenna for reception of the uplink GRB signal and an Earth coverage antenna to provide a downlink relay to the supporting ground sites. DRGS sites may be anywhere in the earth coverage area of the satellite out to a design minimum antenna elevation of 5° degrees.

2.1.1 Interface Identification

Figure 2-1 shows the SS-to-GRB interface. The required connectivity through the GOES-R Series satellites is shown in Figure 2-2. Not shown in this figure are other links that support downlinking of the instrument data (Sensor Data or SD) and the transponder support to the other ancillary services.

Figure 2-1: SS-to-GRB Interface Diagram

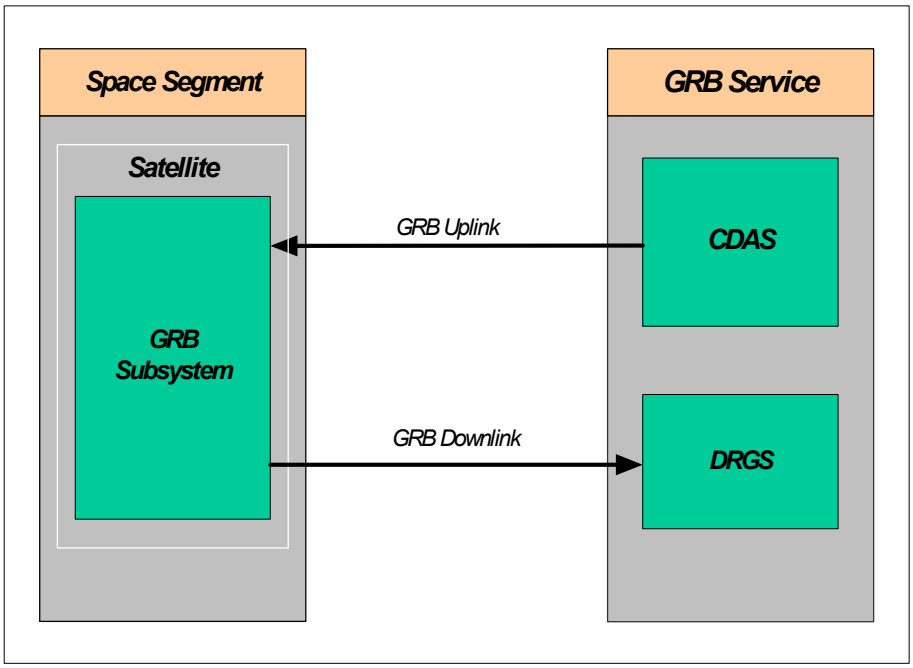
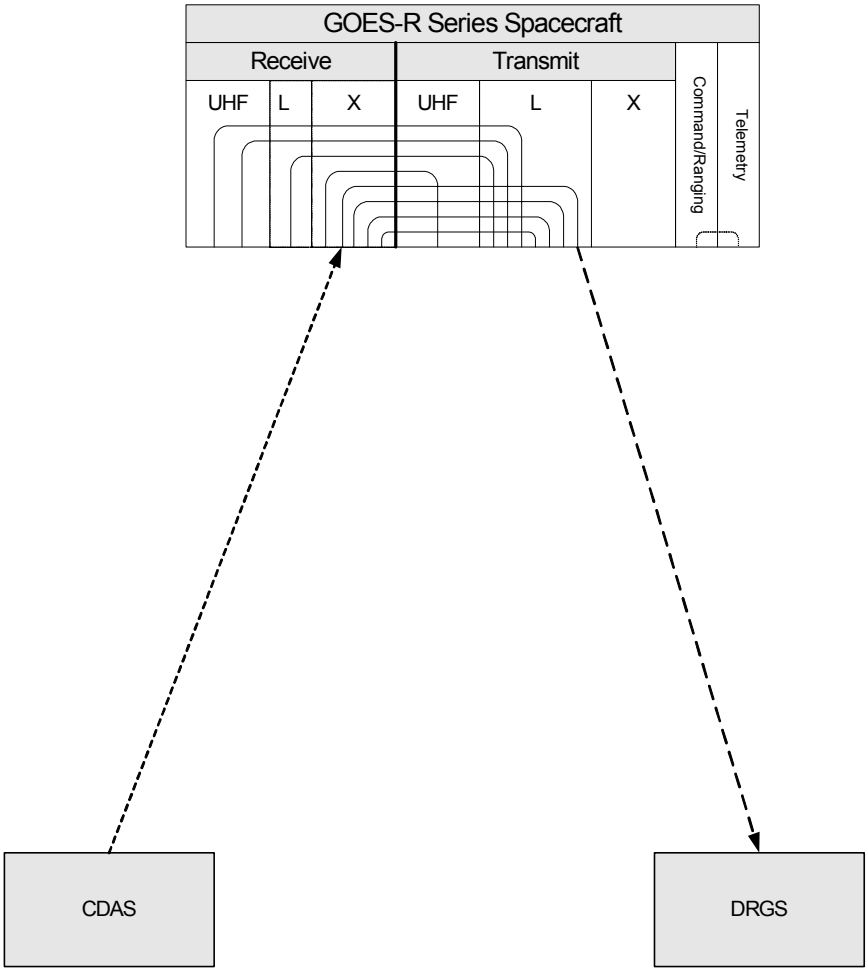


Figure 2-2: GRB Connectivity through GOES-R Series Satellites



GRB GOES Rebroadcast
DRGS Direct Readout Ground Station
CDAS Command and Data Acquisition Station

Table 2.1.1-1 illustrates the GRB interfaces between the GOES-R satellites, CDAS, and DRGS.

Table 2.1.1-1: GRB Interface Identification

	Parameter	Value
	Modes of operation	Broadcast GRB data streams
A	NOAA ground stations	CDAS at Wallops, VA CDAS-West antenna CDAS-East antenna SOCC in Suitland, MD East antenna West antenna Backup CDAS at NASA GSFC for GOES East & Center, Backup CDAS at Fairbanks, Alaska for GOES West
B	GOES satellite transponders	GOES-East GRB transponder GOES-West GRB transponder
C	Types of ground terminals	DRGS, SOCC Other varied GRB users

2.1.2 Interface Description

The GOES-R ABI (imager) and HES (sounder) data communications system functions similarly to its counterpart in the GOES N-P system. The GOES-R satellite GRB link can accommodate the GRB data streams generated from the advanced imager and sounder instruments with higher data rates. The two raw instrument data streams from GOES -East and GOES -West are received at the CDAS, where they are filtered, amplified, downconverted, and output first to both Sensor Data Processing Systems (SDPS) and second to both Product Generation and Distribution Systems (PGDS). Each ground system, one per satellite demodulates, decodes, processes, reconstructs, and generates a unique instrument data stream, which is then uplinked to the satellite for broadcast to users. The ground support equipment calibrates and normalizes imager and sounder data. The data stream also includes satellite navigation data, gridding and earth location data and auxiliary products. Sensor Data Processing Systems also acquire star sense data from the instrument data streams, and extract round-trip delay measurements from the GRB broadcast to calculate range information. These ranging observations are sent to the Orbit and Attitude Tracking System (OATS) for orbit and attitude determination. At the SOCC the Level-1B, data stream is input to the Product Monitors (PM's). The PM's monitor the quality of the GRB data and the instrument detectors. The GOES Rebroadcast Data (GRB) channel requirements are described below in Table 2.1.2-1.

The GRB channel will be used to relay the data uplinked at one frequency from the ground at either Wallops Island, CDAS at NASA Goddard Space Flight Center, or GOES-West CDAS at Fairbanks, Alaska for downlinking at another frequency with hemispheric coverage to appropriately equipped ground receiving stations: Direct Readout Ground Stations (DRGS).

Table 2.1.2-1: GOES Rebroadcast Channel Requirements

	Item	Value
	Satellite	
A	Uplink Frequency	TBD
B	Uplink Bandwidth	12 MHz [TBR], within the requested band of 7190-7235 MHz
C	Downlink Bandwidth	12 MHz, bandwidth of 1683-1695 MHz [TBR]
D	Downlink Frequency	1689 MHz [TBR]
E	Uplink and Downlink Polarization	Linear North-South
F	EIRP downlink	60 dBmi [TBR]. Contractor to propose at PDR; shall be incorporated into ICD.
G	Ground Coverage	Earth hemisphere to a minimum antenna elevation of 5 degrees as seen from the nominal GOES position.
	Ground	
A	Information Data Rate	15 Mbit/s [TBR]
B	Data Format	Contractor to propose, NRZ required
C	Modulation	QPSK [TBR]
D	Coding	Punctured Turbo Code, rate 7/8 [TBR]
E	Ground G/T	15.2 dB/K
F	Data Shaping	A root raised cosine filter will be incorporated in the uplink GRB channel hardware. The rolloff factor is 0.35 [TBR]. A similar filter will be incorporated in the ground receiver equipment.
G	Ground Receiver Loss	For the purposes of link calculations the ground receiver implementation loss is to be assumed equal to 2.3 dB
	Link	
A	Data link availability	99.9% at 5° antenna elevation in the worst month (Crane region D2)
B	BER	Less than $1 \cdot 10^{-6}$

2.1.3 GRB Functional Interface Requirements

This section contains the uplink and downlink physical interface requirements between the GOES-R satellites, CDAS, SOCC and Direct Readout Ground Stations.
The CDAS will transmit the two independent GRB data streams using the CDAS GOES antenna systems. The CDAS encodes data, generates QPSK modulated signals, and transmits the signals to the satellites via uplink frequencies.
The uplink signals pass through the ground to space channel where they experience path loss, rain loss, and gaseous attenuation. Typically the CDAS GOES -West and CDAS GOES -East large parabolic antennas are pointed with approximately 15.2° and 46.1° elevation angles to the GOES-West and GOES-East satellites, respectively. A 5° CDAS antenna elevation angle is used for the worst case link budget to accommodate scenarios where a GOES satellite is repositioned to a new or temporary orbital slot.
The GOES satellite receives the signal via an X band Earth coverage antenna, translates the center frequency to L band, and retransmits it via a linearly polarized L band Earth coverage antenna. Both GOES-East and GOES-West use the same center frequency
The downlink signals pass through the space to ground channel where they experience path loss, rain loss, gaseous attenuation, and scintillation effects. The DRGS's receive the signal via a linearly polarized L band parabolic antenna, demodulate the data, decode and process message packets. The DRGS sites can reside anywhere in the Earth coverage antenna pattern. The link budget assumes the worst-case elevation angle.

2.1.4 Commandable Gain

A command capability to limit the spacecraft EIRP **shall** be provided.

2.1.5 Uplink Parameters

Table 2.1.5 -1, 2, and 3 summarize the GRB uplink interface requirements from the CDAS to a GOES satellite.

Table 2.1.5-1: GRB Uplink Parameters - NOAA CDAS

	Parameter	Value
	Ground Transmitter	
A	User data rate	See Table 2.1.2-1
B	Center frequency (MHz)	See Table 2.1.2-1
C	Uplink EIRP	105 dBmi (TBR)
D	Modulation	NRZ-L, QPSK Phase error: < ±1° (TBR) Amplitude error: 0.2 dB (TBR)
E	Band-limiting filter Spectrum, out of band	-30 dB at ± 6 MHz from center frequency (TBR)
F	Long-term frequency stability	≤ ±1 ppm, all effects (TBR)
G	Carrier phase noise (deg rms)	≤ 1° rms [TBR]
H	Uplink Dynamic Range	10 dB
I	Antenna polarization Polarization alignment error	See Table 2.1.2-1 Matched to satellite nominal ±5° (TBR)
K	NPR, spurious levels (dBc)	At least 23 dB (TBR), ≤ -60 dBc (TBR)

Table 2.1.5-2: GRB Uplink Parameters - Channel

	Parameter	Value
A	Topocentric range (km)	41,100 km for 5° elevation 40,000 km for 15.2° CDAS 37,300 km for 46.1° CDAS 35,800 km for 90° subnadir
B	Link availability	See Table 2.1.2-1
C	Rain and atmospheric attenuation loss (dB)	0.6 dB [TBR]
D	Up-link Modulation Sidelobe level (dBc)	< -30 dBc (below the peak of the main modulation lobe at the antenna input)

Table 2.1.5-3: GRB Uplink Parameters - Satellite

	Parameter	Value
	Satellite Receiver	
A	Center frequency	TBD
B	Antenna coverage	Earth coverage
C	Antenna polarization Polarization alignment error	See Table 2.1.2-1 ±5° [TBR]

2.1.6 Downlink Parameters

Tables 2.1.6 -1, 2, and 3 summarize the GRB downlink interface requirements from the GOES-R satellites to DRGS terminals.

Table 2.1.6-1: GRB Dowlink Parameters - Satellite

	Parameter	Value
	Satellite Transmitter	
A	Downlink frequency stability	$< \pm 1 \cdot 10^{-9}$ when measured over a 0.1-second interval [TBR], $< \pm 3 \cdot 10^{-6}$ long-term [TBR]
B	Antenna coverage	See Table 2.1.2-1
C	Antenna polarization	See Table 2.1.2-1
D	Total EIRP (dBmi)	See Table 2.1.2-1

Table 2.1.6-2: GRB Dowlink Parameters - Channel

	Parameter	Value
	Downlink channel	
A	Downlink ground antenna elevation angle	> 5°
B	Topocentric range (km)	41,100 km for 5° elevation 35,800 km for 90° subnadir
C	Link availability	See Table 2.1.2
D	Rain model and region	Crane region H
E	Rain and atmospheric attenuation loss (dB)	0.4 dB

Table 2.1.6-3: GRB Downlink Parameters - NOAA SOCC and DRGS

	Parameter	Value
A	Ground Receiver	
B	Receiver station locations	Almost anywhere on the Earth within satellite coverage where the antenna elevation angle is ≥ 5°
C	Center frequency (MHz)	See Table 2.1.2-1
D	Dynamic range (dBmi)	-88 to –78 dBmi [TBR]
E	Antenna polarization Polarization alignment error	See Table 2.1.2-1 Matched to satellite nominal ±5° [TBR]
F	Error correction decoder	See Table 2.1.2-1
G	G/T at POB (dB/K)	See Table 2.1.2-1
H	Phase noise (deg rms)	≤ 3° rms [TBR]
I	Demodulation detection filter	Matched filter for SOCC Matched filter for DRGS
J	Demodulation	NRZ-S, QPSK
K	User Data rate (Mbit/s)	See Table 2.1.2-1

2.1.7 End-to-End Performance Parameters

Table 2.1.7-1 summarizes the GRB end-to-end link performance requirements between the CDAS, GOES-R satellites, and GRB user terminals.

Table 2.1.7-1: GRB End-to-End Link Performance Parameters

	Parameter	Value
A	Required end-to-end BER	See Table 2.1.2-1
B	Theoretical Eb/No (dB) for BER = 1E-8	5 dB
	Distortion impacts:	
C	Ground segment loss (dB)	See Table 2.1.2-1
D	End-to-end system margin (dB)	The worst case end-of-life (all the elements in the link set to worst case) link margin is 3 dB minimum with the “as specified” ground segment and weather loss

3 Ground Station Requirements

The downlink GRB signals may be received at L-Band by either or both the Direct Readout Ground Stations (DRGS) and the NOAA SOCC.

3.1 Receive (DRGS and SOCC)

3.1.1 Receive Frequency Band

The overall receive frequency band is in Table 2.1.2-1.

3.1.2 Receive G/T

The DRGS G/T is as described in Table 2.1.2-1. This includes any antenna mispointing. Tracking is not required.

3.1.3 Receive Polarization

The antenna polarization **shall** be linear North-South (N-S) with a minimum cross-polarization isolation of 20 dB [TBR] over the specified coverage area.

3.1.4 Demodulation

The DRGS or SOCC demodulators **shall** be capable of demodulating the downlinked GRB signal.

4 Space Segment (SS) Requirements

The Space Segment (SS) requirements consist of receiving the CDAS uplink and signal, downconverting the X-band to L-Band, and transmitting this signal to DRGS Terminals.

4.1 CDAS-to-SS Uplink Interface

4.1.1 Frequency Band

The uplink X-band frequency signal has 12 MHz bandwidth described in Table 2.1.2-1.

4.1.2 Satellite Receive G/T

The satellite receive G/T **shall** be as described in Table 2.1.5-3.

4.1.3 Satellite Receive Antenna Coverage

The satellite receive antenna coverage **shall** be earth coverage as described in Table 2.1.2-1.

4.1.4 Satellite Receive Antenna Polarization

The satellite receive antenna polarization **shall** be as described in Table 2.1.2-1 with a minimum cross-polarization isolation of 30 dB over the specified coverage area.

4.2 SS-to-DRGS Downlink Interface

4.2.1 Frequency Band

The downlink frequency band is described in Table 2.1.2-1.

4.2.2 Satellite EIRP

The downlink EIRP **shall** be as described in Table 2.1.2-1.
The downlink maximum EIRP **shall** be below the legal PFD limit after taking into account transponder parts variability and environment changes.

4.2.3 Satellite Transmit Antenna Coverage

The downlink satellite transmit antenna coverage **shall** be earth coverage to a minimum elevation angle as described in Table 2.1.2-1.

4.2.4 Satellite Transmit Antenna Polarization

The downlink satellite transmit antenna polarization **shall** be linear as described in Table 2.1.2-1 with a minimum cross-polarization isolation of 30 dB [TBR] over the specified coverage area.

5 Link Performance Specification

Performance is specified for the combined up and downlinks, i.e., for the full path between CDAS antenna and GRB user terminals.

5.1 Assumed Link Parameters

The following conditions **shall** be assumed in the calculation of expected link performance.
Propagation impairments as described in Table 2.1.5-2 on the uplink and on the downlink as described in Table 2.1.6-2 **shall** be assumed.
Scintillation losses **shall** be considered to be 1.5 dB [TBR] for both the up and downlinks; however, it may be assumed that scintillation occurs independently on the up and downlinks and is not simultaneous.
Elevation angles at the DRGS Terminals **shall** be assumed to be the worst case value as described in Table 2.1.6-3.
Worst-case polarization mismatches on the uplink and downlink **shall** be assumed.
Interference accesses **shall** be assumed to be small and no specific entry is required.
At the GRB DRGS Terminal receiver, the theoretical Eb/N_0 **shall** be as described in Table 2.1.7-1 before applying (a) an ground receiver loss described in Table 2.1.2-1, and (b) a satellite distortion and other loss of 2 dB. [NOTE: loss values TBR].

5.2 Link Availability

The link calculations **shall** demonstrate link closure, i.e., positive link margin, under the assumptions specified in Section 4.1. Due to the propagation environment at these frequencies, link availability is high as described in Table 2.1.2-1.

5.3 Link Bit Error Rate

The end-to-end link bit error rate (BER) **shall** be as described in Table 2.1.2-1 or better under the worst case assumptions.

6 Interface Control Document Plan

The provisions of the following ICDs will govern the implementation and operation of the interface described in this IRD:
[TBD]

7 TBR/TBD Listing

Number (SS/GL-C3)	Description	Resolution Plan	Date
TBR1			

8 Requirements Verification Traceability Matrix

This section contains the SS to GRB IRD Requirements Verification Traceability Matrix. As noted in Section 1.1 of this document, the IRD requirements are derived from the GOES-R Level 2 requirements, and thus, the IRD requirements are traceable to the parent requirements documented in the GOES-R Mission Requirements Specification.

IRD Rqmt No. (SS/GL-C3)	IRD Requirement Title	Trace	Trace-Comment
4.1.1	Spectrum Utilization	LVL2: 3.1.11	

9 Abbreviations and Acronyms

ADS	Archive and Distribution Segment
ATMS	Advanced Technology Microwave Sounder
ALC	Automatic Level Control
AM	Amplitude Modulation
AS	Archive Segment
β	Modulation Index
BCH	Bose-Chaudhuri-Hocquenghem (Forward Error Correction Code)
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
C3S	Command, Control and Communications Segment
CDA(S)	Command and Data Acquisition (Station)
CCSDS	Consultative Committee on Space Data Systems
C/N_0	Carrier to Noise Density Ratio (dB-Hz)
CrIS	Cross-Track Infrared Sounder
CTV	Compatibility Test Van
DCPI	Data Collection Platform Interrogate
DCPR	Data Collection Platform Report
DMSP	Defense Meteorological Satellite Program
DSN	Deep Space Network
DSNUG	Deep Space Network Users Guide
EDR	Environmental Data Record
EIRP	Equivalent Isotropically Radiated Power
EMWIN	Emergency Managers Weather Information Network
EOS	Earth Observation System
GL-C3S	Ground Located - C3 Segment
GPS	Global Positioning System
GRB	GOES Rebroadcast
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
G/T	Gain-to-Noise Temperature Ratio (dB/K)
HRD	High Rate Data
ICD	Interface Control Document
IDPS	Interface Data Processing Segment
IPO	Integrated Program Office
IRD	Interface Requirements Document
ITU	International Telecommunications Union
L-Band	1 - 2 GHz Frequency Band

LEO	Low Earth Orbit
LRIT	Low Rate Information Transmission
LVL2	Level Two
MMC	Mission Management Center
NSA	National Security Agency
NASA	National Aeronautics and Space Administration
NTIA	National Telecommunications and Information Administration
NOAA	National Oceanographic and Atmospheric Administration
NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRZ-L	Non-Return to Zero - Level
NRZ-M	Non-Return to Zero -- Mark
OQPSK	Offset QPSK (Also referred to as SQPSK - Staggered QPSK)
PBT	
PCM	Pulse Code Modulation
PM	Phase Modulation
PSK	Phase Shift Keying
QPSK	Quadrature Phase Shift Keying (modulation)
RCT	Real-Time Critical Telemetry
RHST	Real-Time Health and Safety Telemetry
RHT	Real-Time Housekeeping Telemetry
RF	Radio Frequency
SAR	Search and Rescue
S-Band	2 - 4 GHz Frequency Band
SD	Sensor Data
SMD	Stored Mission Data
SOC	Satellite Operations Control
SOH(T)	State of Health (Telemetry)
SQPSK	Staggered Quadrature Phase Shift Keying (Also called OQPSK)
SRS	Satellite Requirements Specification (GOES-R)
SS	Space Segment
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TDRSS	NASA Tracking and Data Relay Satellite System
TRD	Technical Requirements Document

USG	United States Government
X-Band	8 - 12 GHZ Frequency Band